U.S. Department of Agriculture Agricultural Research Service February 1990

# Agricultural Research



Managing the Medfly Menace

## *Relating to Insects*

You're invited to embark on an issueful of amazing tales from the insect world.

Timely tales they are. As we enter the nineties, new outbreaks of the medfly, the "insect of the eighties," are again making headlines.

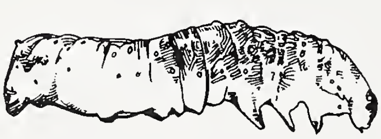
Agricultural Research Service writer Marcia Wood's feature, *Snuffing the Fruit Fly,* spotlights the medfly and several other agriculturally significant, non-native fruit flies.

The offspring of these troublesome insects are slender maggots that can turn once-appetizing produce into a soggy, disgusting mess. Few fruits and vegetables are impervious to their attack: As one beleaguered agricultural official in Southern California said of medfly's eating habits, "If *you* can eat it, *they* can eat it."

The matter of fruit flies has particular meaning for Hawaii. There, much of the untreated fruit is banned from leaving the islands, for fear that stowaway maggots might be hiding inside.

On Oahu, Hawaii, and Kauai, scientists with the ARS Tropical Fruit and Vegetable Research Laboratory are fighting back. They've recruited an air force of tiny wasps, lethal to fruit flies.

They're also readying hordes of sexually sterile male fruit flies that leave a legacy of infertile eggs.



In Utopia, pernicious insects would change their crop-spoiling habits and exclusively turn their voracious appetites against undesirable weeds. On Earth, however, if we wish to permanently alter the behavior of our insect foes, we can do little more than gaze hopefully in the direction of genetic engineering. And readers of **Agricultural Research** already know how chancey a business transferring genes from organism to organism can be: The technology is painstakingly slow and fraught with difficulty.

So it's cheering to discover that creative thinking has taken scientists a bit farther down the gene-transfer road. In *Paving the Way for Altered Crop Pests,* writer Jessica Morrison Silva reveals how an entomologist's desire to stay out of a rainstorm caused him to modify his experiment, substituting an old, familiar piece of equipment called a vortex. Eureka!—a new system for swapping genetic material that may pay insect-altering dividends in the years ahead.

Beginning on page 8, the *Systematic Entomologists* calls some of ARS' insect identifiers front and center. Writer Dvora Aksler Konsant zeroes in on our favorite band of taxonomists, scientists concerned with matters of insect identification and classification.

A dedicated crew they are, merrily poking about in cow dung, poring over trays of crisp beetles for hours at a time, even on occasion receiving treatment for bubonic plague contracted in the line of duty—all to nail down the sometimes miniscule differences that distinguish one insect from another.

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Cover: Mediterranean fruit fly, *Ceratitis capitata.* © Max Badgley

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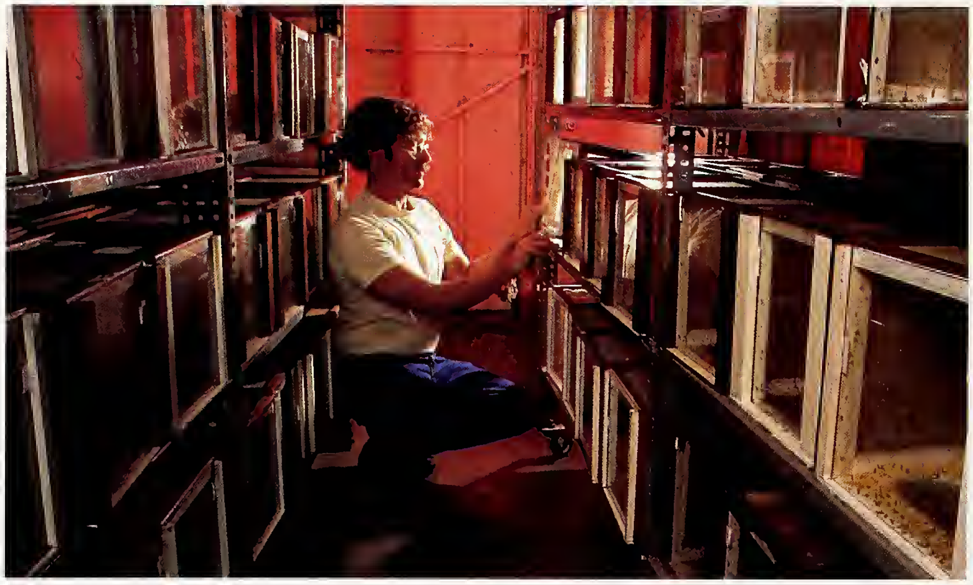
# SNUFFING THE FRUIT FLY



**Technician Michael McKenney observes wasps reared for biocontrol of fruit flies. (K-3496-1)**

About a dozen times each year, destructive fruit flies such as the Mediterranean fruit fly manage to sneak into California from Hawaii or other lush tropical locales.

The insects are a menace to anyone who enjoys eating fresh fruits and vegetables from California. That's because produce from a zone flies have infested can't leave that part of the state until agricultural officials are satisfied the invasion is snuffed out.

All four species are already troublesome residents of Hawaii. And each would happily adapt to California, Arizona, Texas, Florida, and other sunbelt states where their lives might literally be a bowl of cherries, if not an orchard of them.

Fruit flies are small, delicately colored, and essentially gentle. Despite the havoc they raise in fields and orchards, the flies are harmless to humans.

Among all four target species, the female is perhaps more responsible for most of the irreversible damage to vulnerable crops.

She probes crops with her sensitive, needle-like ovipositor, searching for a suitable place to lay her eggs. But each inquisitive stab, or sting, leaves a small puncture—a perfect port of entry for microorganisms that promote rot and decay.

When she finds a likely home for her eggs, she'll inject them just under the skin. The slender maggots that develop from those eggs feed on the fruit or vegetable making it unmarketable and hastening rot.

The maggots eventually fall to the ground from the rapidly deteriorating crop, transform into pupae, and later emerge as adult flies, eager to mate and continue the cycle.

To prevent incoming flies from getting a foothold, states such as California post and monitor thousands of traps on trees year-around—a sort of early-warning system. In the case of medfly, finding even one adult fly in a trap is enough to start agricultural officials scurrying to put up dozens more traps (pinpointing the invasion), to get the OK to apply insecticide (if more flies are discovered), and to begin importing what often amounts to millions of sterile male flies.

When those flies mate with fertile females, no viable eggs are produced. If sterile males outnumber and outcompete their wild counterparts, females won't be able to find a fertile mate, and the population will die out.

The idea of using sterile insects is credited to a retired ARS scientist—Edward F. Knipling—who proved in the 1950's that the tactic could rid the United States of the screwworm fly. Later, ARS scientist Loren F. Steiner and colleagues at Hawaii proved the sterile insect technique could work

with fruit flies. Now, releasing hordes of sterile flies is one of several tactics the Hawaii scientists are relying on in two major new experiments on the island of Kauai. The studies may pose the severest test yet of ploys for safely and effectively thwarting fruit flies—while using minimal insecticide.

If the tests, which will extend over the next 5-10 years, succeed, Kauai may become the first island in Hawaii to rid itself of the oriental, melon, and Mediterranean fruit flies. (The fourth fruit fly pest—Malaysian fruit fly—doesn't live on Kauai.)

JACK DYKINGA

**Papaya infested with Oriental fruit fly larvae. (K-3483-14)**

The first target: part of the Moloaa region on Kauai's northeast coast. "In this small pocket of Kauai, we'll soon find out what works—and what doesn't," says J.E. Gilmore, director of ARS' Tropical Fruit and Vegetable Research Laboratory locations on Kauai, Oahu, and Hilo.

The goal at Moloaa is to depress fly numbers so low that the papaya crop in some 80 acres of groves won't have to undergo the extra processing otherwise required to ensure it's free of flies.

Protection will come, in part, from a new border of corn plants that now surrounds some of the groves, says entomologist Nicanor Liquido.

The corn, planted three rows wide, serves as a natural decoy crop for the female melon and oriental fruit flies that like to roost there, he says. Plants are sprayed with a very small quantity of an insecticide, malathion, that's mixed with a protein-rich, molasseslike food bait.

Attracted to tasseled corn, flies feed hungrily on the tasty mix. When they come in contact with the malathion, they die.

For males, another type of fatal feast is in store. Researchers plan to dot the orchard with thousands of bucket traps.

A cotton wick inside each bucket contains a powerful lure plus malathion. "Once flies get inside the bucket and try to feed on the lure, the insecticide nails them," says Gilmore.

Bucket traps are environmentally sound because they are almost completely self-contained and require very little insecticide. Even so, the University of Hawaii's Institute of Environmental Quality will monitor insecticide levels in water, soil, and foliage throughout the study.

For their final assault, researchers plan to unleash millions of small, black wasps—harmless to people—to destroy fruit fly eggs and larvae (maggots).

Research entomologist Tim T.Y. Wong will use *Psyttalia fletcheri* wasps to attack melon fly and *Diachasmimorphia longicaudata* to stop the oriental fruit fly. Both parasites were brought to the islands for biological control several years ago. But the Kauai experiment will be the first time that ARS researchers will have reared so many of the insects for so big an experiment.

Already, Wong has had unprecedented success in rearing and releasing a related wasp species to attack medflies for experiments on the island of Maui. "We were the first to use sterile flies in combination with beneficial wasps," says Wong. "We were able to knock the medfly population down to a level at least 20 times smaller than the previous year's. I don't see any reason why it shouldn't work as well with these other wasps and flies on Kauai."

Meanwhile, some 30 miles away on the opposite side of Kauai, scientists have launched what they hope will grow into an islandwide attack on the Mediterranean, melon, and oriental fruit flies. Again, their plan


JACK DYKINGA

features a careful mix of environmentally safe strategies.

The study, based at the Barking Sands section of the U.S. Navy's Pacific Missile Range, took off at a run when growers—intent on raising coffee for gourmet markets—planted 166 acres near Barking Sands.

"Medflies love coffee," says Roger I. Vargas, who is in charge of the Moloaa and Barking Sands ventures. The medfly population burgeoned to 100 times its previous level; scientists hurried to blitz the groves with millions of sterile flies. "Steriles are the only control coffee growers can turn to," explains Vargas. "No insecticides are approved for use on the crop.

"And although we'll eventually want to treat the whole island with sterile flies, right now we're targeting only the heavily infested 'hot spots' such as the coffee groves."

It takes a ratio of at least 50 sterile males to each fertile male to economically stamp out a wild population. The bulk of these sterile males will spend part of their life in a small lab ARS is building at Barking Sands.

Laboratories on the island of Oahu will ship sterile flies, still in their resting, or pupal, stage to Barking Sands. Later, they'll be released as young adults.

Improvements from ARS scientists, such as an "egging tube" Roger Vargas and co-researchers developed, have streamlined the process and kept costs down. The tube is a length of white plastic, 4 inches in diameter. Caged adult females deposit their eggs into holes drilled in the tube. Later the eggs are easily collected from inside the tube by flushing water through it.

The researchers may choose a special strain of sterile medflies for release at Barking Sands. Originally developed by scientists in Israel and the Netherlands, the unusual flies have a valuable trait—pupal cases of the males are almost always brown, while the female cases are usually white, explains ARS research geneticist Donald O. McInnis. That means the sexes can be sorted quickly and easily by machine, saving the expense of raising female flies that aren't needed for sterile release.

A high-speed color-sorting machine—the kind used on assembly lines—segregates 1 million pupae an hour. If the insects prove to be as strong and as competitive as other laboratory-reared sterile flies, they may be recruited for Kauai.

And, once the island's medflies are vanquished, scientists hope to zero in on oriental and melon flies by spraying fine droplets of lures spiked with small doses of malathion. "If we can get permission to use this material, we'll apply only an extremely small amount of the insecticide—about a thimbleful per acre," says laboratory director Gilmore.

◀ **Entomologist Nicanor Liquido places fruit fly traps in a papaya grove to monitor populations. (K-3491-8)**

▶ **Technician Dale Kanehisa examines irradiated medfly pupae that will be used for the sterile fly release program on Kauai. (K-3495-17)**

JACK DYKINGA

"We'd start in a small area, about 50 square miles or nearly 7 percent of the island, and track the fate of the chemical in the environment. If, at the end of 2 years of study, we've confirmed that there's no health hazard, or adverse effect on soil, water, foliage, or species such as beneficial insects, fish, birds, or small animals, we'll ask for the OK to go islandwide with the attack."

Researchers want some help from sterile males of both fly species. "For the attack on the oriental fruit fly, we may release sterile males in some special areas such as water reservoirs," says Gilmore. "With the melon fly, we'll want to use sterile males after the proposed spraying to clean up any remnants."

If the strategies on Kauai prove successful, agencies such as the Hawaii Department of Agriculture and USDA's Animal and Plant Health Inspection Service might propose similar campaigns on other fly-infested Hawaiian islands.

A fly-free Hawaii could offer not only a more diversified selection of locally raised produce for markets, restaurants, hotels, and overseas buyers, but better tasting fruits and vegetables as well. "If you didn't have the flies, you could let the fruit ripen naturally and have a higher quality product," says John D. Stark, research entomologist in charge of the day-to-day operations at Moloaa.

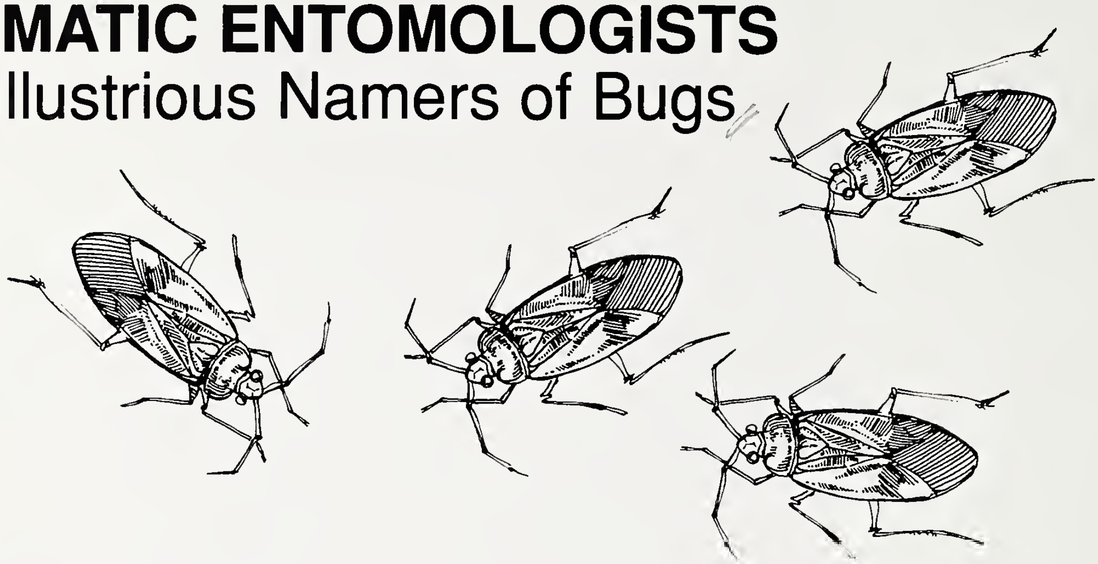
"Right now, fruits such as papaya have to be picked before they're fully ripe. The riper they get, the more vulnerable they are to fruit flies."

The four species of flies the scientists are chasing aren't native to Hawaii and aren't wanted there, says J.E. Gilmore. "We've learned a lot about them from our research, and we think we now have the weapons we need to fight back, without disrupting the environment.

"Fruit flies are a hassle for everyone in the islands, whether you just want to grow a few tomato plants in your backyard or a grove of papayas on an acre or two. Visitors who've only seen the crowded beaches here might disagree, but Hawaii really is a tropical paradise. Count on it to be even more so—once we're rid of these doggone flies."—By **Marcia Wood,** ARS.

*All of the scientists mentioned here are with the USDA-ARS Tropical Fruit and Vegetable Research Laboratory: J.E. Gilmore, Tim T.Y. Wong, Roger I. Vargas, and Donald O. McInnis are at P.O. Box 2280, Honolulu, HI 96804 (808) 988-2158; Nicanor Liquido, P.O. Box 4459, Hilo, Hawaii 96720 (808) 959-9138; and John D. Stark is at Kauai Branch Station, P.O. Box 1330, Kapaa, HI 96746 (808) 822-7995.* ◆

# SYSTEMATIC ENTOMOLOGISTS
## Those Illustrious Namers of Bugs



There are about 1 million of them out there. And those are just the ones we've named. There may be 10 to 50 million kinds we don't know about.

What are they? Insects.

Before scientists design a biological control program to protect crops from marauding insects, they must know which species cause the problem and which ones feed on the pest. Before port inspectors can let a shipment of fruit from South America come into this country, they have to be certain the insects crawling among the crates are not harmful.

That's where ARS' Douglass R. Miller and his colleagues come in. They identify these and other insects that affect agriculture.

"Our work is the foundation of all work with insects," says Miller, research leader of the Systematic Entomology Laboratory (SEL), located at Beltsville, Maryland, and Washington, D.C.

"And sometimes it's not as easy as it would seem," he adds, "since two insects that look alike might be different species. Yet another two that look quite different might be the same species."

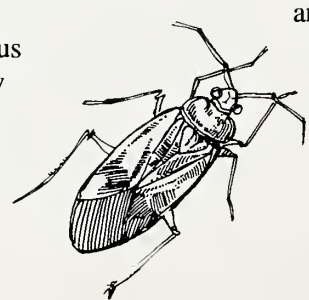
An insect's name is the key, according to Miller. Anyone anywhere should be able to look up the name and from that find out all that is known about the insect. Much of ARS' insect identification is done in the backrooms at the Smithsonian Institution's National Museum of Natural History. ARS and Smithsonian entomologists have worked together for 108 years to create an incredible collection of over 30 million insect specimens.

"The collection is our primary resource," says Miller. "It's like a library we're always updating. To identify an insect, we note its physical characteristics—things like wing type, size, color, and shape of genitalia—as well as its habitat, behavior, and predators. We create catalogs and identification keys and are computerizing the information about the world's insects."

There are 31 orders of insects. ARS scientists study 16, the ones that are agriculturally beneficial or detrimental. These include flies, termites, moths and their destructive caterpillars, wasps, beetles, and bugs.

The work done by these systematic entomologists helps farmers, nursery workers, port inspectors, homeowners, biologists, ecologists, and other entomologists.

These illustrious bug-namers know more than one could ever guess about how to tell one insect from another. Here are some of their stories:



### Wise About Flies

F. Christian Thompson is turning bound catalogs about flies into a computer database that taxonomists and other scientists can use to more easily get information about insects.

He's also creating a biosystematic information system—an expert system that should help anyone, including nonentomologists—figure out which insect is which.

"It will include not only an insect's physical characteristics," he says, "but where it occurs, what it eats, what eats it, where it comes from, and its economic importance."

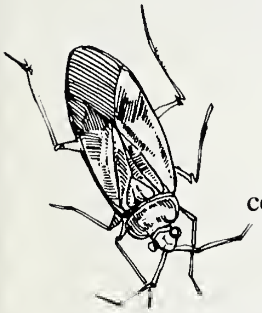
At this point, he's close to having a prototype program completed for fruit flies. He says the program, which can display descriptions, drawings, and photos on the computer monitor, could probably be geared toward any insect.

### The Call of the Cricket

David A. Nickle collected termites and katydids from the Peruvian Amazon as leader of an Earthwatch expedition (funded by the Earthwatch Foundation). So far he's collected 260 species from a small area in northern Peru (as

Entomologist Alma Solis examines a European corn borer moth specimen. (K-3480-1)

KEITH WELLER



compared to 230 already known to occur in all of Peru, and 107 in the United States).

Nickle works with grasshoppers and mole crickets (pests that feed on crop seedlings and pasture) and termites and cockroaches (pests of houses and other manmade structures).

He is the only ARS scientist studying orthopteran bioacoustics—the songs katydids and crickets make to attract mates. He can even mimic them. "You can hardly tell some cricket species apart, except by their songs," Nickle says. "Once you can distinguish them by their songs, you can then find subtle morphological differences that can be used to identify them."

According to Nickle, analysis of the waxy material on cockroaches and termites (cuticular hydrocarbon) is one example of biochemical identification techniques.

"Since these hydrocarbons differ from species to species, they might be used as 'fingerprints,'" he says. "We don't know their function yet, but it may have to do with the way insects recognize members of their species."

The best way to identify these insects is to use all three methods: behavior, morphology, and biochemistry, Nickle says.

### Moths, Moths, and More Moths

Ronald W. Hodges studies "little gray-brown moths." These are the adult stage of gelechioid moths whose caterpillars include pink bollworms and needle miners and pests that eat crops such as cotton, potatoes, stored grains, and coniferous trees (pines and firs).

Hodges says, "Slight differences in a moth don't necessarily make it a different species. A bit bolder stripe across the wing, for example, could be a separate species or just an individual nuance. My hair is brown, yours is blond, but we both belong to the same species."

Hodges is cataloging all the North American gelechioid moths (about 2,000 species); worldwide, 10,000 to 15,000 have been described, out of an estimated 50,000.

"All the information about insects—pest, beneficial, or ornamental—is stored according to scientific name. For practical purposes, this classification is the necessary first step to using and discussing them," says Hodges.

M. Alma Solis studies the pyralid moths, including the ones that infest the flour and corn meal in kitchens.

"They're ugly insects, actually," she says. "But each time I look at a moth, it's like opening a little present and getting surprised. We're always adding information," she reports.

Her small office contains all the moth and butterfly caterpillars in the museum—only 144 drawers. That's as compared to seven rows (100 feet long, each with 2,904 drawers per row) of adult moths.

This graphically demonstrates the limits to our knowledge of caterpillars, Solis says. There is so little information about them, even though they are the stage that causes damage.

Solis is studying all of the moth's life stages: caterpillar, pupa, and adult. She will be taking a rather unique approach to her studies—statistically measuring body parts to separate them by species.

"At the species level," she says, "many characteristics vary continuously, such as the length of the wing. This approach measures the variation and is an attempt to define a species by those measurements."

"The pyralids could be the second largest family of Lepidoptera (butterflies and moths) in the world," she says. "Still, there's not a lot of information on tropical moths, so we really don't know how many of them there are."

More than 4 million specimens of Lepidoptera are stored at the Smithsonian Museum of Natural History in Washington, D.C. Entomologist Alma Solis examines a few. (K-3480-9)

KEITH WELLER

The largest family of moths are the noctuids, or cutworms. These include the top two pests of U.S. agriculture—the corn earworm and the tobacco budworm. Together, this voracious pair causes about $1 billion of damage annually in the United States.

Robert W. Poole, who studies cutworms, advises "know thine enemy." In the course of his studies, he found that the tobacco budworm was not 2 species, but 15.

"Two of the species are important pests, but the other 13 are not," Poole says.

He thinks studying an insect's biochemistry as well as its morphology, behavior, ecology, and genetics, might help to better identify these moths. "Knowing these things about related species might help to develop controls for the economically important ones," he says.

One noctuid larva from Florida, that Poole identified, turned out to be hard on citrus growers' irrigation systems. The larva, when it's ready to become an adult, normally bores into the stem of woody, leguminous weeds for a pupation site. But instead of using the weed as a haven, the worm preferred boring into trickle irrigation pipes, creating unwanted sprinklers around the orchard.

## Desperately Seeking Jake

E. Eric Grissell has one drawer of little wasps, hardly the size of a pen point. "And those are the big ones," he says. Some of these wasps are so tiny that almost 400 adults can parasitize one cabbage worm pupa. Other wasps lunch on egg, larval, or adult stages of insects.

When he's not squinting at the tiniest wasps, Grissell spends much of his time providing correct names for the parasitic wasps that are important in biological control. He works on half of the 2,500 North American species. There are about 18,000 worldwide by some estimates.

"They are poorly known, though. There could be five times as many species," he says. "Some of the wasps we know about have been named more than once." Grissell reviews scientific papers, catalogs, identification keys, and museum specimens to make sure that the right name is always associated with the right wasp.

"You could call a bug 'Jake,' he grins, "but a port inspector or a farmer in Russia or France or Brazil still has to be able to identify it. It is critical that everybody calls it Jake."

To correctly identify parasitic wasps important to biocontrol, entomologist Eric Grissel reviews catalogs, scientific papers, identification keys, and museum specimens. (K-3481-1)

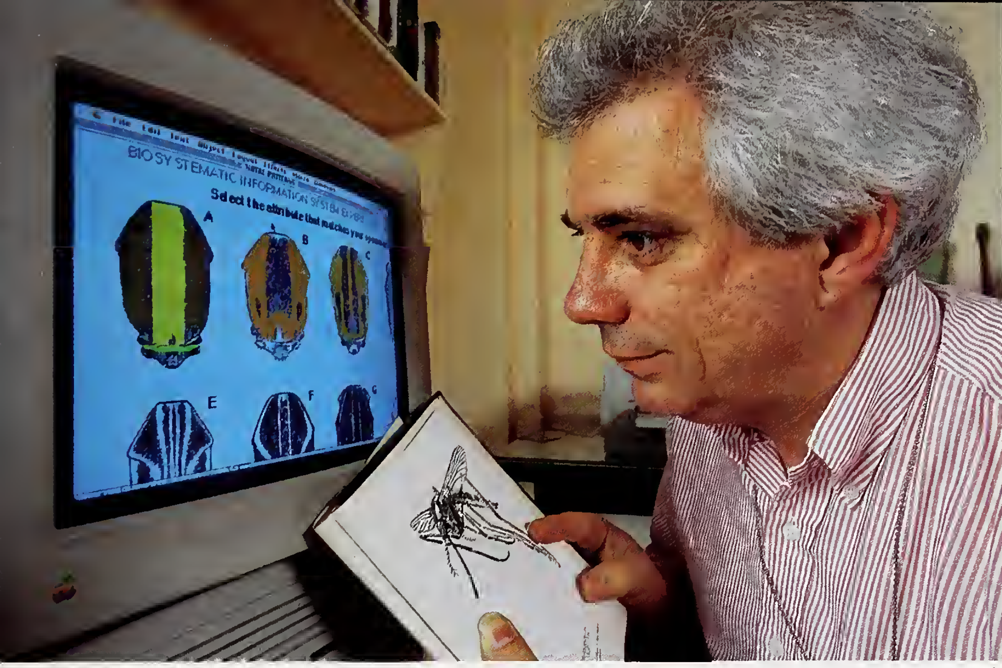
KEITH WELLER

## A Follower of the Beetles

Robert D. Gordon works on two groups, lady beetles and dung beetles. The latter help return nutrients, especially nitrogen, to the soil.

Some of these beetles, the larger ones, carve out bits of the dung and roll them away to use for food. The smaller ones either burrow into the dung, feed in place, and lay eggs, or they carve out a chink and bury it under the pat.

"Dung is actually a pretty big problem in some parts of the world,



KEITH WELLER

Even novices will be able to use the computerized insect identification system that entomologist F. Christian Thompson is developing. (K-3481-8)

including the United States," Gordon says. In Australia, for example, there are no native beetles to help reduce the buildup of cow dung. Scientists are importing these beneficial creatures to help alleviate the problem.

Gordon spends about 1 month a year traveling in search of dung beetles, an occupation that is not without its hazards. While collecting in Texas, he developed flu-like symptoms, a tremendous headache, and a fever of 105°F. He had been bitten by a flea that infected him with bubonic plague, the same disease that wiped out one-quarter of Europe's population in the 14th century. Antibiotics cured him (of the plague, if not his dung beetle-collecting habits).

### They're Bugs, Real Bugs

Thomas J. Henry doesn't study wasps, moths, or beetles. He studies bugs. He collects, names, and classifies Heteroptera, or true bugs. These insects have sucking mouth parts and a wing that's half membrane, half hard chitinous material. As the fifth largest order of insects, it includes bed bugs, squash bugs, stink bugs, plant bugs, damsel bugs, and pirate bugs.

Henry specializes in plant bugs, including those that eat ornamental plants and crops; some of the more infamous are lygus bugs, the cotton fleahopper, and the alfalfa plant bug. But not all plant bugs are pests, he says. Many are beneficial, preying on certain pests, such as scale insects and lace bugs. "One of the most remarkable bugs actually lives in spider webs," says Henry. It is neither beneficial nor harmful.

"I recently finished a 10-year project cataloging 4,000 species of plant bugs in North America," he says. The catalog covers literature back to 1758, from Linneaus, who is called the father of zoological nomenclature. (This date marks the start of the system for scientifically naming animals with Latinized words for the genus and species.)

Even though the catalog is "hot off the press," he says, it won't be long before an update will be needed to document the many newly discovered species and constantly changing nomenclature. That's how rapidly the literature is evolving.

### Gall Midges: He Wrote the Book

Raymond J. Gagne, who studies little flies called gall midges, describes his new book, a guide for identifying over 900 species of plant midges. It's replete with life-size illustrations of the damage the insects cause to plants and many drawings of the microscopic characteristics used to identify the larvae.

Gall midge larvae suck the juice from plants and damage them by stunting or causing various kinds of galls on fruits, flowers, and leaves. Many species, for example, the Hessian fly and the sorghum midge, are serious plant pests.

"Anybody can use the guide," Gagne says. "It's nontechnical enough for a layperson to find which midge is on his or her ornamental plant, but is also a basic research tool for scientists."

The book, a product of 25 years of museum research and collecting in the field, is the first guide of its kind since 1940. Individual chapters cover the biology, anatomy, and distribution of gall midges and explain how to collect, rear and prepare specimens. Gagne says the book also covers fungus feeders and predators.—By **Dvora Aksler Konstant**, ARS.

*You've just read about nine of the SEL's entomologists located at the Smithsonian. They and their colleagues at the Beltsville Agricultural Research Center can be contacted through the USDA-ARS Systematic Entomology Laboratory, Bldg. 003, BARC-W, Beltsville, MD 20705 (301) 344-3183.* ◆

# BRIGHTENING TRITICALE'S FUTURE

A century ago, when triticale, the first manmade grain, was crossbred, little note was made of the achievement. Today, rave reviews seem belatedly in order.

According to a report by the National Research Council (NRC), this cross between wheat and rye could help support burgeoning populations in a world faced with possible climate change.

Step by step, scientists have developed triticales that yield up to 30 percent more than wheat on marginal lands. And studies such as those conducted by ARS plant geneticist J. Perry Gustafson of Columbia, Missouri, may help propel triticale into the limelight again.

He's identifying useful genes in both wheat and rye and hopes to find ways of making them work effectively in interspecies crosses. Such research lays the groundwork for genetically engineering selected genes into plants of the future.

The triticale hybrid of today is grown mostly for livestock feed, but progress made so far in breeding for flour quality may shift its use more toward breadmaking. Triticale is now grown on about 1.2 million acres in Poland and 1.8 million acres in other countries, including some 120,000 acres in the United States.

Because of possible climate changes caused by the greenhouse effect and the limits of intensive agriculture, triticale will increasingly be grown on marginal lands throughout the world, the NRC report predicts.

From triticale's beginnings, the idea of crossing wheat and rye was to transfer disease resistance between species.

Progress was slow at first, because the seed was usually sterile. Then advances in breeding began to overcome this problem in the 1950's, stimulating seed sales in the 1960's by entrepreneurs who promoted the crop as a high-yielding, high protein crop with

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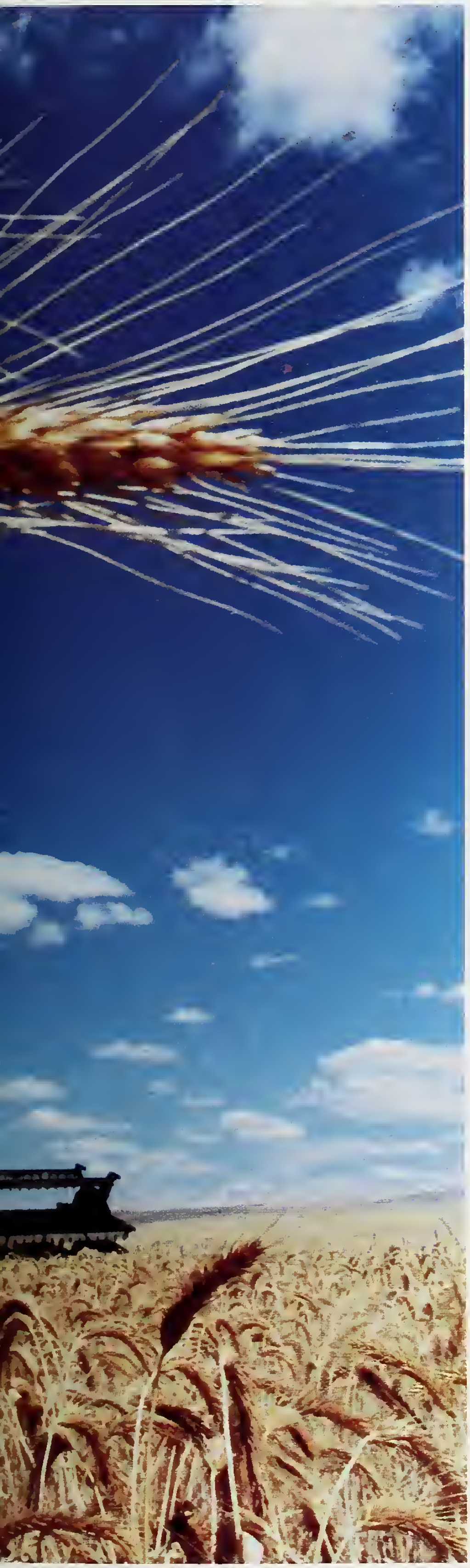
Harvesting triticale near The Dalles, Oregon.



a huge market potential. Farmers responded by planting nearly a quarter million acres annually, but acreages soon dropped dramatically as it was discovered that the claims were overrated. Research to evaluate triticale had not proceeded as quickly as the rise in the crop's popularity.

Today, some triticales are notably more resistant than wheat to major cereal diseases—leaf blotch, powdery mildew, smuts, and bunts. And some of the disease resistance found in many modern wheat varieties came about because genes of rye have found their way into wheat lines.

Research conducted mostly by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico points to other advantages of triticales: ability to thrive on soils that are high in aluminum or boron or are saline, sandy, acidic, alkaline, cold, infertile, dry, or mineral deficient.

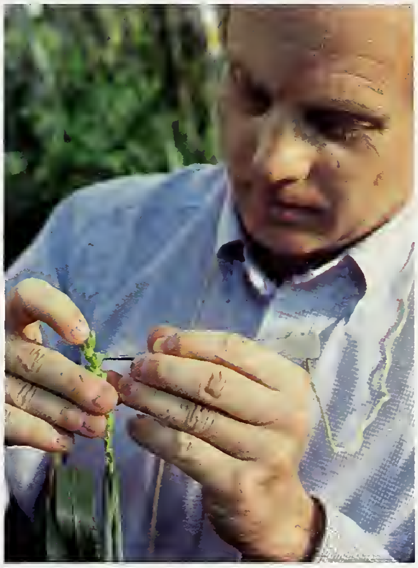
Studies by ARS agronomist Leland E. Francois of the U.S. Salinity Laboratory, Riverside, California, have demonstrated that some varieties of triticale, as well as barley and cotton, tolerate salinity well in irrigated soils such as those in California's Imperial Valley.

As scientists learn how one gene may affect action of another, it may be possible to make triticales even better adapted to specific soil conditions. In a recent study, Gustafson and biological laboratory technician Kathleen M. Ross found wheat genes that enhanced the ability of triticale to withstand high levels of acid and aluminum common in about 86 million acres of U.S. cropland.

Some of the genes that enhance acid and aluminum tolerance are on the same chromosome as genes associated with flour qualities that make bread doughs rise well. This happy coincidence improves the prospects that conventional breeding can increase triticale's usefulness in human foods.

Already, some triticale flours produce doughs that rise as well as those made from wheat flour, according to the NRC report, which described bread made from triticale flour as tasty, having a slightly nutty flavor. The flour is used in French-style bread in Brazil and in pancake mixes and crackers sold in some specialty food stores in the United States. Triticale is also being used for making foods in Europe, Mexico, and Australia.

BOB NICHOLS



**At his Columbia, Missouri, laboratory, plant geneticist Perry Gustafson prepares a triticale head that will be used for making hybrid crosses. (K-3458-1)**

Gustafson says immediate wide-scale use of triticales in bread are unlikely, though. Baking technology and consumer habits in bread selection throughout the world are oriented to wheat flour. Still, as high-yielding varieties of triticale become more widely grown as a livestock feed, the economic merit of including it in human foods may become increasingly obvious.

Triticale tolerates moderate drought quite well as does its rye parent, but unfortunately, some insects, including Russian wheat

COURTESY OF GENE HETTEL, CIMMYT

**Today's triticale varieties (left) are plumper than earlier varieties with better fertility and higher smut tolerance.**

aphids, thrive under the same conditions, says James A. Webster, an entomologist with the ARS Wheat and Other Cereal Crops Research unit at Stillwater, Oklahoma.

From among the 731 breeding lines in the USDA-ARS National Triticale Collection at Aberdeen, Idaho, Webster has identified resistance to Russian wheat aphid in 7 of them. Next step: He's incorporating all seven lines into a wheat breeding program. This research, along with efforts to import and identify the most promising natural enemies of the aphid, may help reduce farmers' need to rely on insecticides.—By **Ben Hardin,** ARS.

*J. Perry Gustafson is in USDA-ARS Cereal Genetics Research, Curtis Hall, Room 208, University of Missouri, Columbia, MO 65211 (314) 882-7318. Leland E. Francois is at the U.S. Salinity Research Laboratory, 4500 Glenwood Drive, Riverside, CA 92501 (714) 369-4835. James A. Webster is in USDA-ARS Wheat and Other Crops Research, 1301 N. Western, Stillwater, OK 74075 (405) 624-4200.* ◆

# Puzzling Microbe Thrives In Cold Food

Agricultural Research Service scientists are investigating the life cycle of a relatively obscure food pathogen.

The pathogen—*Aeromonas hydrophila*—isn't as well known as other harmful bacteria such as *Salmonella* or *Listeria,* nor does it pack the same punch. But this food-invading bacterium found primarily in water, has an uncanny ability to withstand and grow at cold temperatures, says microbiologist Samuel A. Palumbo, who is with ARS' Microbial Food Safety Research unit in Philadelphia.

"People were never that conscious about it in food," Palumbo says. "At present, it is not considered 100 percent pathogenic."

Nevertheless, Palumbo and colleagues at Philadelphia are tracking *A. hydrophila's* growth and living conditions.

Some studies done elsewhere indicate that *A. hydrophila* can break down red blood cells and cause infection. But the body's natural immune system generally seems to fight it off pretty well, Palumbo says. It has been blamed for diarrhea and vomiting in children, the elderly, and in immune-deficient people.

The pathogen was not thought to grow on food, but experiments have proven its viability—even at refrigerator temperatures. Although it grows best at 75°F—completing a growth cycle in a day at 80°F—experiments indicate that at 40°F, it still completes a normal growth cycle in about 14 days. Its tolerance to cold is still being investigated.

*A. hydrophila* is readily killed by cooking. Palumbo says that at 110°F, it begins to die and that foods such as steak cooked medium-rare should be free of the pathogen.

Pasteurizing dairy products and curing meats also destroy *A. hydrophila.* The pathogen is sensitive to salt, nitrite, and acid pH, which could be manipulated in food processing to control growth.

Each factor affecting the growth and survival is being compiled into a computer program that predicts the exact environmental conditions for pathogen growth, Palumbo says. This information will help food companies predict the response of *A. hydrophila* to food processing and handling conditions and ensure safer products to the consumer.—By **Bruce Kinzel**, ARS.

*Samuel A. Palumbo is in the USDA-ARS Microbial Food Safety Research Unit, Eastern Regional Research Center, 600 E. Mermaid Lane, Philadelphia, PA 19118 (215) 233-6524.* ◆

# IRRIGATE? WHY NOT CHEMIGATE?

Imagine flipping a switch to automatically water, fertilize, and pest-proof crops. A measured quantity of pesticide is automatically released at a controlled rate into the irrigation water by equipment designed for this purpose.

It's been happening for some time already. A growing number of farmers who irrigate are looking at sprinklers as a cheaper and more environmentally sound way to apply pesticides as well as fertilizers. Mixing weed killers and other chemicals with irrigation water often has benefits over spraying by airplane or tractor.

There's a notable safety advantage: Applying chemicals in irrigation water—dubbed chemigation—eliminates the need for any one to be in the field when the chemicals are being applied.

Another advantage is economic: Chemigation generally costs from a third to half that of aircraft or tractor applications.

It can be an environmentally sound way to apply certain pesticides. In some cases, chemigation enables farmers to reduce total chemical quantities; two smaller applications may be made over two or more irrigations. It stands to reason that using less of a chemical reduces the possibility of leaching to ground water, a growing concern among environmentalists and farmers.

One way of testing this supposition is by computer model. The U.S. Department of Agriculture recently modified its main groundwater pollution model to evaluate the leaching potential with chemigation techniques on various crops and soils.

Called GLEAMS, for Groundwater Loading Effects of Agricultural Management Systems, the model runs simulations for up to 50-year cycles.

The model includes weather data compiled from 1936 to 1985 at the Coastal Plain Experiment Station near Tifton, Georgia.

Ralph A. Leonard, soil scientist and project leader with USDA's Agricultural Research Service in Tifton, says, "We need to see what can happen under all possible weather situations, including dry and wet years and everything in between."

After the latest change in GLEAMS to include chemigation, the scientists ran simulations with 10 major herbicides and one nematicide, a chemical used to kill nematodes in the soil.

Chemigation, an economic and safe way of applying pesticides. (K-2308-15)

They simulated chemigation and conventional applications for each pesticide on two soil types, chosen to represent two extremes commonly found in the Southeast: one a well-drained, and therefore highly leachable, sandy soil; the other, a poorly drained (much less susceptible to leaching) clay soil. GLEAMS has data stored on the relevant characteristics of each type.

The researchers compared their long-term simulations with limited short-term field data from other experiments at Tifton. They found the simulations agreed reasonably well with the field data. This gives them confidence that with further improvements, GLEAMS can be used to evaluate the leaching potential of pesticides under different chemigation systems.

Although the average losses favored chemigation, there were years in the simulation when leaching was higher with chemigation. This happens in wet years when rainstorms follow chemigation.

Leonard says chemigation is not a magic solution to potential groundwater contamination. "It doesn't cause a chemical to behave differently. But for the many pesticides that work well when delivered in multiple applications, you may get the same benefits by using less pesticide."—By **Don Comis,** ARS.

*Ralph A. Leonard is at the USDA-ARS Southeast Watershed Research Laboratory, P.O. Box 946, Tifton, GA 31794 (912) 386-3462.* ◆

# PAVING THE WAY FOR ALTERED CROP PESTS

BARRY FITZGERALD


**Laboratory technician Henry Neier uses a vortex mixer to insert new genes into house fly embryos, a much faster method than microinjection. (K-3469-7)**

"It's kind of like being in a jacuzzi with a porcupine."

The way geneticist Andrew F. Cockburn talks of his new genetic engineering technique, it sounds like a kinky twist to a romantic weekend retreat in the mountains.

That technique, Cockburn says, "could make genetic engineering of pest flies—and possibly grain crops—feasible and practical where it never has been before." It may lead scientists to create flies that don't bite or crops that yield more grain.

The "jacuzzi" Cockburn speaks of is actually a vortex mixer, an ordinary piece of lab equipment commonly used to spin and mix chemicals. His "porcupine" is a set of whisker-thin silicon carbide needles. The "bathers" are fly eggs and foreign genes.

"Each time a needle gently touches an egg," Cockburn says, "a tiny hole results. That hole allows some of the genetic material to enter it."

He stresses that genes that actually cause beneficial changes in flies and crops still need to be found, but that half the battle has been won in just finding a way to penetrate cells.

Cockburn and technician Henry Meier, both in ARS' Insects Affecting Man and Animals Research Laboratory at Gainesville, Florida, developed the method for fly eggs. They've already shared it with crop scientists at the University of Florida who are adapting it for use on citrus and rice cells.

ARS has filed a patent application for the method, which is at least a thousand times faster than microinjection, the only genetic engineering method used for fly eggs to date.

In each experimental attempt, the scientists successfully transferred material—either a test gene or dye—into thousands of fly eggs in a few minutes. That's compared to one egg per minute with microinjection, which scientists have been using experimentally for decades.

In microinjection, scientists painstakingly insert a miniature hypodermic needle into an egg while watching it under a microscope. They inject new material, hoping that the egg will survive to incorporate the new genes.

Microinjection equipment costs about $15,000, compared to the $180 price tag on the vortex. "Almost every lab has one," Cockburn says.

And scientists can get the silicon carbide whiskers easily, too. Commonly used in ceramics (they provide the strength to stress-bearing products), the whiskers are made by most suppliers of silicon products.

Cockburn and Meier achieved their incredible success rate with the jacuzzi method on the first try. They suspect they could do even better by altering vortex speed, whisker numbers, and other variables. Further tests are planned to optimize the technique.

The scientists successfully transferred material into eggs of the house

fly, stable fly, Caribbean fruit fly, and the non-pest *Drosophila* fly.

Scientists have been trying for years, without success, to genetically engineer pest insects and grain crops. As Cockburn points out, "Insect eggs and plant cells are designed to keep things out, things like viruses, bacteria, and any DNA we scientists might try to insert."

So two years ago, Cockburn and ARS chemist David Carlson decided to try to blast through that natural barrier. They first tested a gene gun that propels gene-coated pellets into cells. Carlson made the gun in his garage from his grandfather's 22-caliber pistol. In most cases, the pellets either didn't penetrate insect eggs or "squashed them completely," he says. Pellets penetrated a few eggs successfully, but not enough to be useful. *[Other scientists have tried gene blasting. See* Agricultural Research, *June 1989, p. 14.]*

So with a grant from the University of Florida, Cockburn hired Meier and began work on the jacuzzi method.

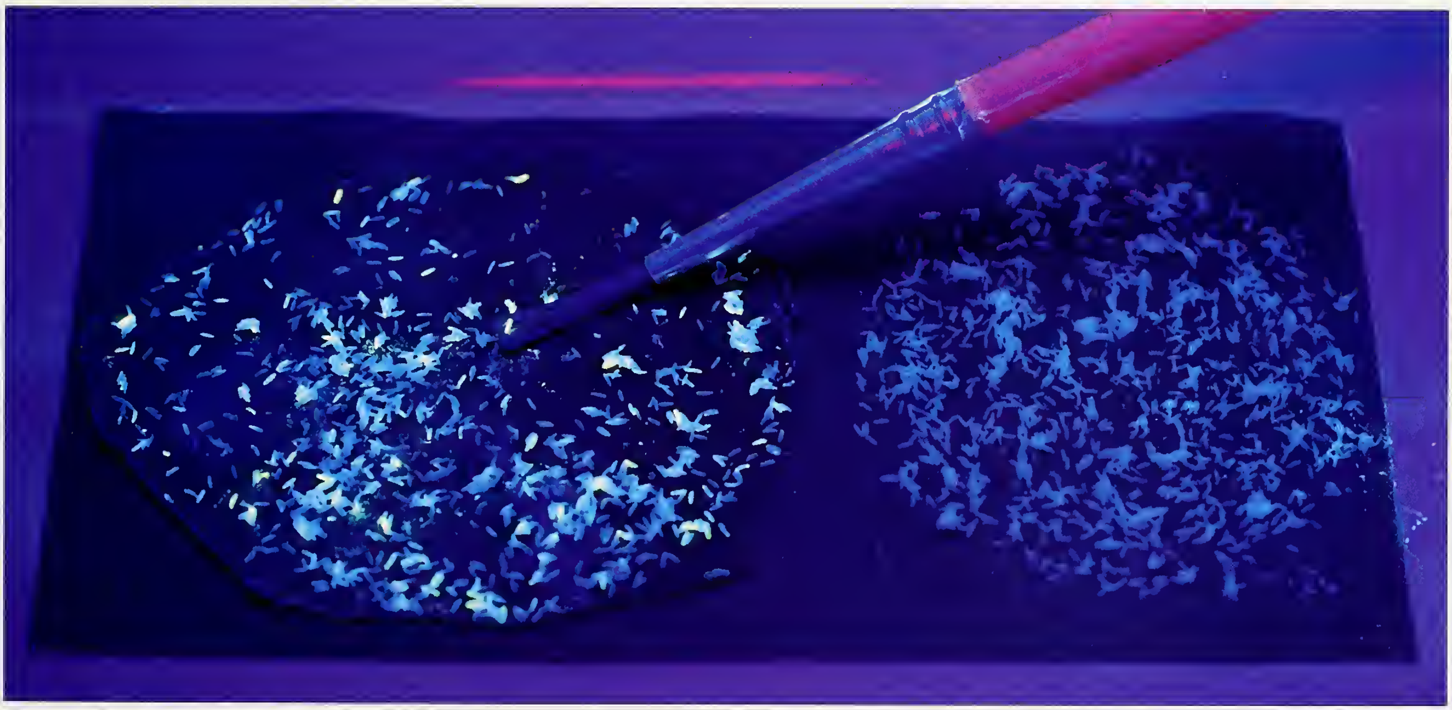
They had originally decided to borrow a nearby lab's sonicator, a chamber in which sound waves shake a mixture rapidly. But one afternoon in Gainesville, torrential rainfall discouraged Meier from walking across the parking lot to the lab next door. He suggested they try the vortex, located right in their lab. Cockburn says, "I laughed and said, 'That's silly, but go ahead.' He did—with such incredible results that we never got around to trying the sonicator."—By **Jessica Morrison Silva,** ARS.

*Andrew F. Cockburn is in the USDA-ARS Insects Affecting Man and Animals Research Laboratory, 1700 SW 23rd Dr., P.O. Box 14565, Gainesville, FL 32604 (904) 374-5873.* ◆

BARRY FITZGERALD

**Geneticist Andrew Cockburn arranges house fly embryos for microinjection. (K-3466-17)**

BARRY FITZGERALD



**Showing the success of the vortex mixer method, house fly embryos glow under ultraviolet light (left) after being injected with a fluorescent dye. (K-3467-6)**

# COUNTERACTING AFLATOXIN IN LIVESTOCK FEED

An anticaking compound used in animal feed could help counteract the ill effects of a natural poison on livestock and poultry, preliminary tests indicate.

The poison, aflatoxin, is produced by several species of *Aspergillus* molds that infect seeds and nuts on growing plants and in storage.

To preclude residues in milk, mixed feed for dairy cows cannot contain more than 20 parts per billion of aflatoxin. Milk has FDA's most stringent aflatoxin limit—0.5 ppb.

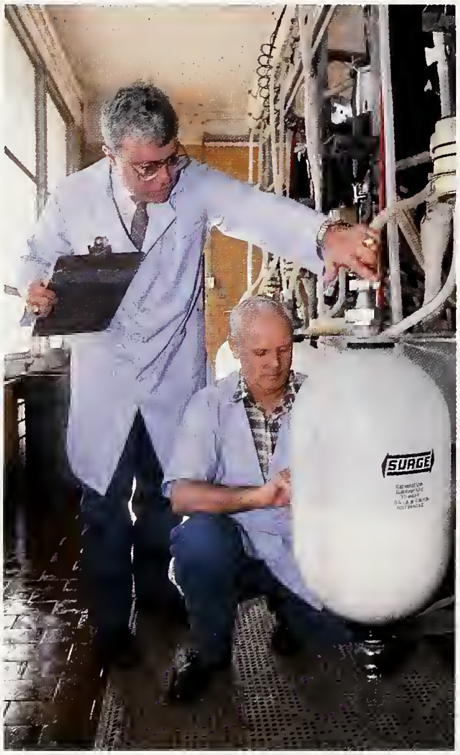
"Very high levels of aflatoxin can cause acute poisoning and may cause liver cancer in humans, but in this country no such cases have been reported. We have safeguards to make sure our food is wholesome," says veterinary toxicologist Roger B. Harvey. He is at the Veterinary Toxicology and Entomology Research Laboratory operated by the Agricultural Research Service at College Station, Texas.

"Aflatoxin can be a problem in poultry and livestock. It costs our poultry industry an estimated $100 million a year in bird deaths and reduced production," says Harvey.

The anticaking compound, hydrated sodium calcium aluminosilicate, or HSCAS, is available commercially. In two 3-week-long tests conducted by a team of ARS and Texas A&M scientists led by Harvey, the compound was added to aflatoxin-contaminated feed given to three dairy cows.

In the first phase, the cows received feed with 200 ppb of aflatoxin, and the aflatoxin levels in their milk were measured. The cows were then fed a diet including both aflatoxin and 0.5 percent HSCAS. Aflatoxin levels in their milk dropped from 1.0 to 0.8 ppb for one cow, 2.1 to 1.1 ppb for the second cow, and 2.6 to 1.8 ppb for the third cow.

DAVID NANCE




**Veterinary toxicologist Roger Harvey (standing) and biological technician Eugene Davee collect milk samples to check control of aflatoxin by HSCAS (hydrated sodium calcium aluminosilicate). (K-3488-18)**

The scientists repeated the routine, increasing the HSCAS level to 1 percent and decreasing the aflatoxin to 100 ppb. Aflatoxin in the milk dropped from 0.65 to 0.27 ppb, 1.1 to 0.45 ppb and 1.4 to 0.65 ppb for the three cows, respectively.

Use of HSCAS to reduce aflatoxin in feeds would require approval from the Food and Drug Administration, Harvey notes.

"More extensive tests are needed, but the findings are significant, particularly since this is one of the few instances where you find an antidote that appears to be specific for a single toxin," he says.

In a preliminary study in 1984, two dairy goats were given aflatoxin with and without 2 percent HSCAS.

"There was a 60 percent reduction in aflatoxin residues in the milk of the goat dosed with HSCAS," Harvey says. "But in the goat that didn't get any HSCAS, 1.5 percent of the aflatoxin we gave ended up in the milk." More aflatoxin-feeding stud-

DAVID NANCE

**Biological technician Maurice Connell preparing milk samples for aflatoxin residue testing. (K-3486-14)**

ies with dairy goats are planned in cooperation with Prairie View A&M University at Prairie View, Texas.

Aflatoxin rarely carries over into an animal's meat, Harvey emphasizes: "The animal acts as a sort of natural filter."

A report on aflatoxin and HSCAS was released in 1987 by Harvey, Timothy Phillips of Texas A&M University, and ARS animal scientist Leon F. Kubena. Their work showed that HSCAS protected chickens against the adverse effects of aflatoxin. [See *Agricultural Research,* March 1988, p. 4] Soon after that, they reported that HSCAS prevented clinical disease caused by aflatoxin in swine.

The anticaking compound binds aflatoxin in the intestinal tracts of chickens and pigs when the substance is added to their feed. "It seemed to tie up aflatoxin so it passed harmlessly through an animal's body," Harvey says.

Harvey and coworkers tested HSCAS' effectiveness against aflatoxin with 30 pigs in studies completed in 1987. Some pigs ate unaltered feed, some ate feed laced with 3 parts per million (ppm) of aflatoxin, some had feed with 3 ppm aflatoxin plus 0.5 percent HSCAS, and some received feed with 3 ppm aflatoxin and 2 percent HSCAS.

At the end of the 4-week study, the control group as well as the pigs with aflatoxin plus HSCAS in their diet had gained an average of about 42 pounds each. But, significantly, the pigs on aflatoxin without HSCAS gained an average of only about 13 pounds each.

Another study, conducted by Harvey and coworkers in 1988, involved 20 six-month-old lambs weighing about 75 pounds each. Five of the lambs received untainted feed with no HSCAS, five received feed with 2 percent HSCAS, five ate feed with 2.6 ppm of aflatoxin, and five ate feed with both 2.6 ppm aflatoxin and 2 percent HSCAS.

The control group, the group receiving HSCAS, and the group receiving both HSCAS and aflatoxin gained an average of about 20 pounds during the 42 days of the test. But the lambs that received aflatoxin-tainted feed and no HSCAS gained only about 2 pounds during the same 6-week period.

In a 3-week test conducted in 1989, 250 young turkeys were fed feed with 1 ppm of aflatoxin, and some of the birds also received 0.5 percent HSCAS.

Weight gains were 50 percent lower for the birds receiving aflatoxin and no HSCAS than for birds in a control group on normal feed but were only 29 percent lower for the birds receiving aflatoxin plus HSCAS.

When the test was repeated with aflatoxin doses reduced to 0.5 ppm, the researchers saw 60 percent protection against reduced weight gains.

Robert J. Oltjen, ARS associate deputy administrator, Beltsville, Maryland, oversees aflatoxin research. "The threat of aflatoxin to people in this country is slight but very real, and we have been attacking it on several fronts," he says.

"We have a lot to learn about how these molds operate, how to deactivate them, and how to better control conditions in which they flourish."

Jane F. Robens, ARS national program leader for food safety and health, adds: "HSCAS is a hopeful beginning in the development of technology that will afford practical aflatoxin control methods for producers."—By **Sandy Miller Hays**, ARS.

*Roger B. Harvey is in the USDA-ARS Mycotoxin Research, Veterinary Toxicology, and Entomology Laboratory, College Station, TX 77840 (409) 260-9259.* ◆

DAVID NANCE

**About a half pound of HSCAS is enough to protect 100 pounds of feed. (K-3488-9)**

**Corn kernel infected with *Aspergillus flavus*, a fungus that produces aflatoxin. (K-3488-19)**

# RIPENING GENE: CAN IT BE CONTROLLED?


JACK DYKINGA

Technician Jean Murphy examines tomatoes at different stages of ripening. (K-3086-9)

Inside fruits and vegetables ripening peacefully in fields, orchards, vineyards and backyard gardens, tiny cell factories vigorously churn out a gas known as ethylene.

In tomatoes, apples, cherries, peaches—hundreds of different kinds of produce—ripening is, scientists think, largely the work of this one compound.

Yet the ethylene that transforms crops from rock-hard and inedible into ripe and ready to eat also makes fresh produce perishable.

Much of the U.S. fresh fruit and vegetable harvest eventually spoils, and some of that waste is blamed on ethylene, according to plant molecular biologist Athanasios Theologis at the Agricultural Research Service/University of California Plant Gene Expression Center, Albany, California.

"Plants are zealous about making ethylene," he says. And once biosynthesis of the colorless, odorless gas starts, it apparently escalates.

But it doesn't have to be like that, say scientists such as Theologis, who envision the day when crops—modified through biotechnology—might ripen at our convenience, not nature's.

Theologis has brought molecular biologists a step closer to making that dream happen. Along with colleague Takahide Sato, now at Chiba University, Matsudo, Japan, Theologis has cloned a gene that plants apparently must have to manufacture the gas.

Now, if scientists can use techniques of modern biotechnology to turn down or turn off the gene, they might be able to slow down the production of ethylene.

Such a feat is likely "5 to 10 years away," says Theologis. If it were to happen, however, tomorrow's less perishable produce should be in better condition, fresher tasting, and more nutritious when it reaches our supermarkets. And these genetically engineered fruits and vegetables should be ideal for export, too. Produce that today ripens too quickly to export successfully should tomorrow ripen slowly enough to be ready to sell when it reaches faraway buyers.

One tempting destination for such crops might be Japan's Mom-and-Pop-style produce stands, where consumers expect fruit to be ripe and ready to eat when they buy it. In another futuristic scenario, fruits and vegetables that now have to be kept in cold storage to slow ethylene formation may someday be stored—less expensively—at room temperature. That should be a boon for tomatoes which lose some of their flavor when refrigerated.

Imagine, too, cut flowers that last longer. That could happen if they were genetically engineered to produce less of the ethylene that today causes them to wither. Carnations, notorious ethylene producers, are among the flowers that might benefit most.

The gene Theologis and Sato cloned instructs fruits and vegetables such as zucchini—the one they used in their experiments—to produce a hardworking enzyme, ACC synthase. "In nature, this enzyme is a catalyst, a sort of spark for one of the final steps leading to ethylene production," says Theologis.

First, ACC synthase acts on a compound called S-adenosylmethionine (SAM). The enzyme converts SAM into 1- aminocyclopropane-1-carboxylic acid (ACC). This, then, is

converted into ethylene by an ethylene-forming enzyme.

Ethylene is one of five powerful hormones that exert strong control over the lives of green plants. Because we are so dependent on plants, scientists want to unlock the secrets of plants' influential hormones. Cloning a pivotal gene, such as the one for ACC synthase, boosts such research. With the gene, scientists now have a new, tangible tool they can use to learn more about how plants make the hormone.

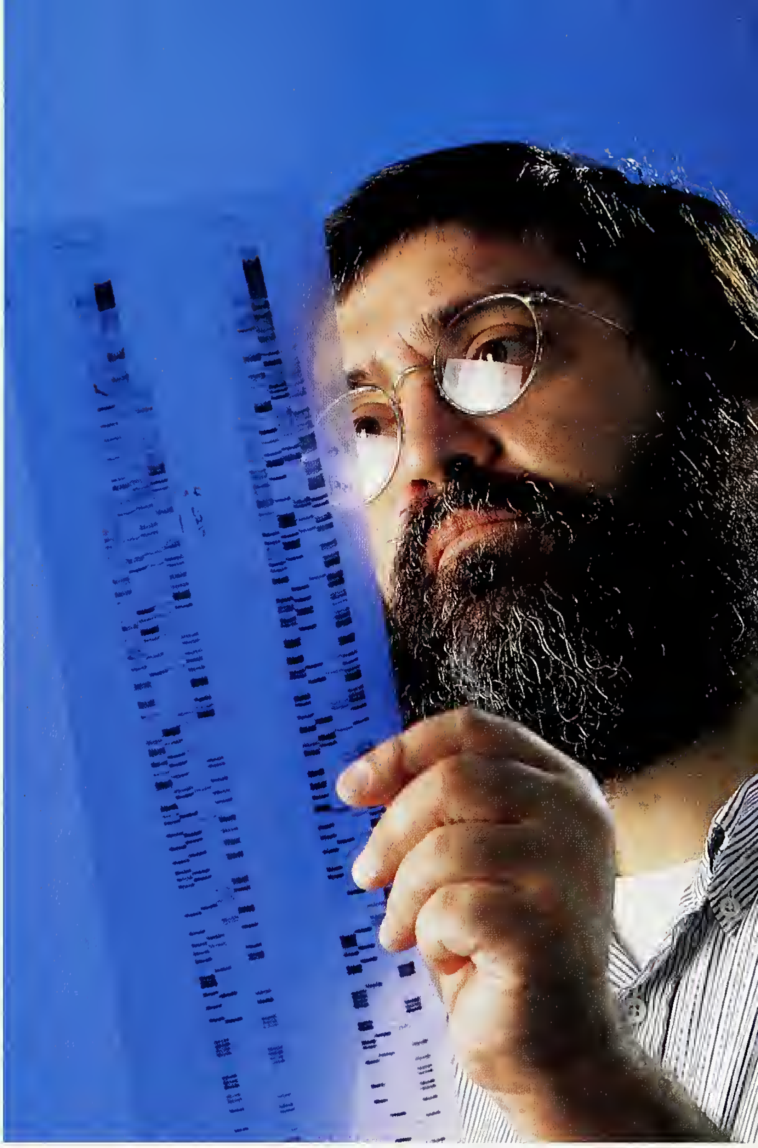
In the world of plant hormone research, the Albany work represents several important firsts. It is the first time anyone has cloned a plant gene that is critical to ethylene production. In fact, it is the first time anyone has cloned a plant gene vital for synthesis of any major plant hormone.

This work has attracted its share of skeptics. As one of several ways to help prove that the gene they cloned really does direct plants to produce ACC synthase, Theologis and Sato put the ripening gene into laboratory microorganisms that don't naturally produce ethylene.

Both the bacterium and the yeast they chose have the compound S-adenosylmethionine—and lots of it. But neither microorganism normally has the ACC synthase- or ethylene-forming enzymes that it takes to convert SAM into ACC, and then into ethylene.

Once Theologis and Sato inserted the newly cloned ACC synthase gene into the bacterium and the yeast, however, the microorganisms responded by making ACC from their supplies of SAM.

Finding the right gene from among the thousands active in ripening zucchini, took 20 months. The team may now need that much time, or more, to test the most promising options to slow down the gene.



JACK DYKINGA

**To determine which genes are related to plant aging, plant molecular biologist Athanasios Theologis uses electrophoresis to separate and match nucleotide sequences of DNA fragments. (K-3489-1)**

Research geneticist Loverine P. Taylor of Theologis' laboratory wants to block production of ACC synthase using a strategy called antisense RNA.

Normally, the ACC synthase—like other plant genes—directs the plant to form a substance called messenger RNA (mRNA). This mRNA, in turn, has the instructions the plant follows to make the ACC synthase enzyme.

Taylor's approach is to have the plant make an additional message—one that is reversed. Scientists think this "antisense RNA" binds to the normal mRNA for ACC synthase, leaving the plant incapable of reading the normal message and unable to make ACC synthase.

Although Taylor started growing greenhouse tomato plantlets containing the customized RNA last summer, she says she'll need more time—and at least two generations of plants—before she will know the new RNA's effects.

William H. Rottman, also a research geneticist with the Albany group, is trying another tactic to outwit the enzyme. He's using a sort of "slasher RNA"—ribozymes that literally hack away at the natural RNA for ACC synthase. Again, the intent is to keep the natural RNA from doing its job.

Another strategy—the least developed yet perhaps the most promising—relies on building an artificial gene. Through what's known as homologous recombination, the gene would aggressively take the place of the native ACC synthase gene. The

important difference between old gene and new would be that the new one would lack the promoter (a piece of DNA that acts like an "on" or "off" switch) needed to start production of ACC synthase for ripening.

Right now, this approach, called gene transplacement, "works beautifully in yeast," says Theologis. "When this technology is developed for plants, it will be revolutionary. We'll be able to manipulate plants' genetic makeup at will."

None of these tactics are easy to pursue. And, although the team is 99 percent certain the ACC synthase gene they cloned is the key to ethylene formation, some scientists have suggested that the enzyme could exist in other important forms, too.

If that's the case, these "isoforms" could be controlled by other ACC synthase genes, not yet cloned. Scientists may have to deal with isoform genes, using other strategies to silence them.

Further, even though ethylene has long been credited with ripening and blamed for overripening, other chemicals of plants may play vital roles, now unknown. If so, genes responsible for those chemicals may need to be manipulated to modify natural ripening.

JACK DYKINGA

**Technician Julie Keller and molecular biologist Athanasios Theologis take samples of pea sprouts for studies on ethylene biosynthesis. (K-3088-1)**

How might these and other scenarios for growing high-tech fruits and vegetables of the future affect a feature most of us consider very important to the food we buy, flavor.

Although no one yet knows for sure how genetic engineering to control ACC synthase will affect the taste, texture, and aroma of fresh produce, the work could bring flavor payoffs, says Theologis.

He explains that tomatoes genetically engineered to produce little or no ethylene, for example, should be able to stay on the vine longer, without deteriorating. "That means they have more time to take up sugars and acids—important to flavor—from the vine."

In contrast, today's tomatoes are typically harvested before they have a chance to rev up ethylene production. That's because, if allowed to linger on the vine, they'd likely soften and spoil on the long trip from grower to grocer.

Detailed probing into the workings of the hormone ethylene may have another, somewhat surprising benefit. The research may yield new clues for medical researchers investigating human hormones such as adrenalin or growth factors, says Joye F. Jones of the National Institutes of Health.

"Plants are wonderful for studying a lot of biological processes that you can't easily investigate in animals—even in a frog," says Jones, in explaining why the National Institutes of Health funded part of Theologis' work.

"Even though the details of how hormones function aren't the same among all organisms, you can use a plant hormone such as ethylene to explore, to manipulate, and to get your ideas worked out. A lot of biological processes are so fundamental that it really doesn't matter what organism you study them in."—By **Marcia Wood,** ARS.

*Athanasios Theologis is at the ARS-University of California Plant Gene Expression Center, 800 Buchanan Street, Albany, CA 94710 (415) 559-5900.* ◆

"When this technology is developed for plants, it will be revolutionary. We'll be able to manipulate plants' genetic makeup at will."

## Afternoon Drop in Photosynthesis

Corn takes a photosynthesis siesta on warm, dry afternoons, according to the findings of ARS plant physiologist James A. Bunce.

This phenomenon, an afternoon decline in the photosynthesis rate, has previously been found only in crops in which carbon dioxide is the limiting factor in the rate of photosynthesis—crops such as soybeans and wheat which are in the C3 category of plants.

C3 plants are so-called because their first product of photosynthesis has only three carbon atoms.

This is the first report of such an afternoon drop in corn, which belongs to the C4 category of plants, where the first photosynthesis product has four carbon atoms.

The C3 and C4 crops followed different evolutionary tracks in developing photosynthesis. The C3 types of crops close their stomates—pores on the leaves through which carbon dioxide enters—to prevent the loss of moisture as temperature rises in the afternoon. The drop in available carbon dioxide causes a drop in the rate of photosynthesis.

But photosynthesis in a C4 type of crop such as corn or sorghum is not limited by carbon dioxide availability. So the photosynthetic rate should not be cut even if stomates on corn plants do shut down to preserve moisture.

"And since corn does not have afternoon stomatal closure, this crop in particular was expected not to show the afternoon drop in photosynthesis," says Bunce. "But it does."

Bunce found that the photosynthetic rate drops about 30 percent on warm, dry afternoons under natural growing conditions. "A drop like that on a regular basis translates to cutting growth by about 10 percent," he says.

It isn't directly the increasing heat of the afternoon that causes the decline. When other conditions are equal, high temperature favors photosynthesis in corn, according to Bunce.

"Lack of humidity around the leaves appears to drive the drop," he says.

When temperatures rose but humidity was kept high, the rate of photosynthesis did not drop.

"But as soon as the humidity directly around the leaves drops, they dry out slightly and the rate of photosynthesis drops, even if the soil around the roots of the plant is wet," Bunce says.

With the source of the drop identified, Bunce expects that it should be possible to find corn varieties that are more resistant to humidity decreases or to breed the potential into commercial varieties.

"It will be easier to screen for higher photosynthesis now that we know what limits it in corn," Bunce says.—By **J. Kim Kaplan,** ARS.

*James A. Bunce is at the USDA-ARS Plant Photobiology Laboratory, Rm. 01, Bldg. 046A, Beltsville Agricultural Research Center, Beltsville, MD 20705 (301) 344-3607.* ◆

## Rating Rice Weeds for Yield Damage

When it comes to weeds, the specific types that appear in fields can make a difference in when and how farmers should take action.

For example, one plant of barnyardgrass in rice crops is as much cause for alarm as three bearded sprangletop weeds, says agronomist Roy J. Smith, Jr. Smith is based at ARS' Rice Production and Weed Control Research unit in Stuttgart, Arkansas.

Smith's feelings about barnyardgrass are more than just personal bias. He and technician Frank Carey, III, have worked with other scientists for 2 years on development of a computer model that calculates the impact of eight major weeds on rice production.

"These eight weeds—barnyardgrass, broadleaf signalgrass, bearded sprangletop, eclipta, northern jointvetch, hemp sesbania, red rice, and ducksalad—account for about 90 percent of our weed problems in rice," he says.

"We used test plots to find the density at which you'd get an effect on yields. We also looked at when in the life of the weeds and rice you'd have the most impact on yields." Effects on both conventional and semi-dwarf varieties of rice were determined.

To use the model, a rice grower would supply information on the type of rice being grown and the type and estimated number of weeds in the fields. The model would then describe potential losses if no action were taken and information on herbicide program options that the grower might use, including cost and effectiveness.

The model could help growers cut back on herbicide use, reducing both production costs and the chance of environmental pollution, Smith says.

"This will help the grower more precisely assess the weed problem," he says. "Even a fairly high density of certain weeds might not cause growers that much of a problem in terms of lost yields. There may be some situations where they won't even want to use herbicides.

"When growers do use herbicides, this could help make the choice easier. If they have a high density of certain weeds and face high yield losses, they may want to go with a top-of-the-line treatment. But if there is a lower density of weeds, a less expensive treatment may do. It will be up to individual growers to choose, but the model can help."

Smith hopes to have the model working this year and to eventually refine the model to deal with scenarios involving combinations of weeds, "such as a couple of grasses and a couple of broadleaf species, which would cover most situations." He said the model could someday be put on a floppy disk that rice growers could use on personal computers.—By **Sandy Miller Hays**, ARS.

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